Ideal ballooning modes in the ASDEX-Upgrade and JET pedestals

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Predictive pedestal modelling typically makes use of two main constraints to determine the pedestal structure: the peeling-ballooning global MHD mode to limit the pedestal height, and the ideal $n = \infty$ ballooning mode (as a proxy for the KBM limit) to limit the pressure gradient. Peeling-ballooning stability is tested by using an MHD stability code (e.g. MISHKA or ELITE), while the $n = \infty$ is often transformed, as in the original EPED model[1], into a relationship between the height and width of the pedestal (the well known Δped $\propto \sqrt{\beta_{pol,ped}}$).
Experiments on ASDEX-Upgrade at different plasma currents (extending the data set presented in [2]) were performed to test the effect of different poloidal fields on the pedestal structure. Predictive scans prior to the experiments indicated that the pedestal top pressure should scale positively with plasma current. In the experiment, across the range of main ion (D) fuelling ($1.5-2.8\times10^{22}$ es^{-1}), impurity seeding (up to 2.2×10^{22} es^{-1}), and heating power (5-15 MW) scanned, the pedestal height is, however, similar at all three plasma currents. Significant deviations (up to a factor of two) from the $\beta_{pol,ped}$ scaling of the pedestal width are also observed.
In this work we use the equilibrium code HELENA to examine the $n = \infty$ ballooning stability at the plasma edge for this set of discharges to test the underlying theory that the pedestal gradient is constrained by ballooning modes. Initial tests on 1.2 MA plasmas have shown that low pressure pedestals (12 kPa) are limited across the entire pedestal width by local ballooning modes, while higher pressure pedestals (17.5 kPa) have access to second stability (effectively no limitation on the local pressure gradient) at the location of the highest gradient.
A previous study of lower current JET pedestals[3] revealed similar phenomenology; high pedestal pressures were obtained only when local ballooning modes were in the second stable region. To extend this analysis, a series of 2 MA JET experiments including a divertor geometry scan and variations in D fuelling ($0.7-10\times10^{22}$ es^{-1}) and nitrogen seeding ($1-5\times10^{22}$ es^{-1}) is compared to the AUG data set.
The work will present the general invalidity of the ”simple” $\sqrt{\beta_{pol,ped}}$ dependence of the pedestal width on both machines and test whether access to second stability is necessary for this scaling to function. Additionally, it will also extend the work presented in [3] to verify if access to second stability is required before pedestals can be limited by peeling-ballooning modes.

References

[1] P. B. Snyder, et al. *Physics of Plasmas*, 16(5), 2009.

[2] M.G. Dunne, et al. *Plasma Phys. Control. Control. Fusion*, 59(3), 2017.

[3] C. Bowman, et al. *Nuclear Fusion*, 58(1), 2018.